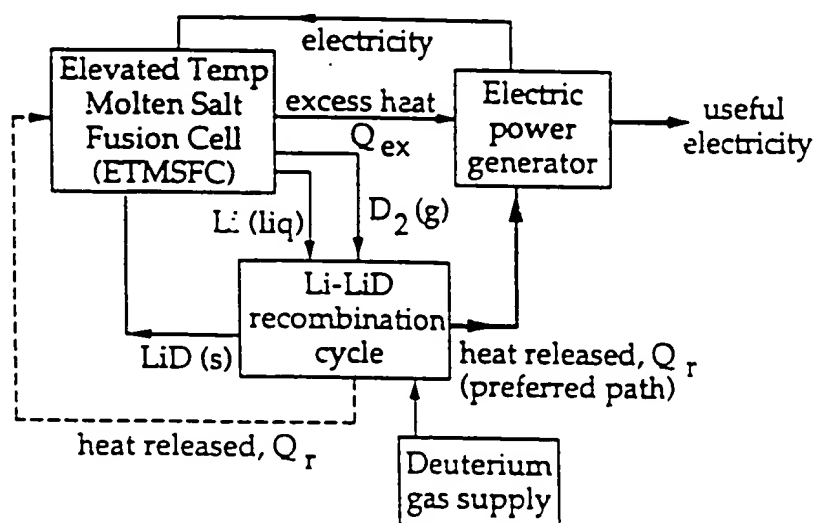




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(21) International Application Number: PCT/US90/06419 (22) International Filing Date: 5 November 1990 (05.11.90) (30) Priority data: PCT/US90/4122 20 July 1990 (20.07.90) WO (34) Countries for which the regional or international application was filed: US et al. (60) Parent Applications or Grants (63) Related by Continuation US 344,679 (CIP) Filed on 28 April 1989 (28.04.89) US 555,517 (CIP) Filed on 20 July 1990 (20.07.90) (71) Applicant (for all designated States except US): UNIVERSITY OF HAWAII [US/US]; Research Corporation of the University of Hawaii, 2540 Maile Way, Honolulu, HI 96822 (US).		(72) Inventors; and (75) Inventors/Applicants (for US only): LIEBERT, Bruce, E. [US/US]; 2216 Mohala Way, Honolulu, HI 96822 (US). LIAW, Bor, Yann [US/US]; 512 Iolani Avenue, No. 302, Honolulu, HI 96813 (US). (74) Agent: HSIA, Martin, E.; Cades Schutte Fleming & Wright, P.O. Box 939, Honolulu, HI 96808 (US). (81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US. Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	

(54) Title: ELECTROCHEMICALLY ASSISTED EXCESS HEAT PRODUCTION



(57) Abstract

Electrochemically assisted nuclear reaction that produces excess heat at elevated temperatures by immersing a metal in an electrolyte solution comprising a molten salt containing an alkali deuteride and applying a potential and current to the electrolyte and the metal to enhance diffusion of deuterium into the metal. A recycling system utilizing metals that do not form compounds with lithium and also have very limited solubilities for lithium will increase the usefulness of the invention by recombining lith-

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DESCRIPTIONElectrochemically Assisted Excess Heat Production
Technical Field

5 This invention relates to electrochemically-assisted excess heat production. Recent reports of excess heat production in electrochemically-assisted metal-deuterium systems have been attributed to fusion.

10 Nuclear fusion occurs when two nuclei of a light element combine in order to form a single nucleus of a heavier element. Nuclear fusion is the process that causes the sun to shine and a hydrogen bomb to explode. The simplest fusion reactions between two deuterium atoms are to form (i) a helium-3 nucleus and a neutron or (ii) a tritium nucleus and a proton. The nucleus of a hydrogen atom consists only
15 of a single positively charged particle, the proton. A hydrogen atom's nucleus may also contain a single neutron and a single proton to form the hydrogen isotope deuterium. A hydrogen atom containing two neutrons and one proton is the hydrogen isotope tritium.

20 The energy in a helium nucleus is less than the energy in two deuterium nuclei, so that if two deuterium nuclei fuse to form a helium nucleus, the excess energy is released; this is the source of energy for a deuterium fusion reaction. However, because deuterium nuclei are
25 positively charged, they repel each other. Accordingly, in order to induce fusion, this repulsion must be overcome.

Background Art

30 Scientists have sought a method for inducing controlled fusion reactions for decades. At this time, at least four major methods have been proposed and are being studied. The first method, magnetic confinement, requires the creation of high temperature plasmas in a confined electromagnetic field in order to overcome the electrostatic repulsion between deuterium nuclei to cause them to fuse. The second method,
35 inertial confinement, attempts to overcome the electrostatic repulsion between deuterium nuclei by simultaneously compressing a deuterium cluster from all directions with powerful laser beams. The third method, muon-assisted

1 fusion, involves the use of muon particles to assist
deuterium fusion. Magnetic confinement and inertial
confinement fusions require very high energies or extremely
expensive equipment.

5 However, the fourth method, electrochemically-assisted
"cold fusion", appears to require only readily available
materials and relatively inexpensive equipment.
Electrochemically-assisted "cold fusion" has been attributed
to deuterium-deuterium or deuterium-hydrogen fusion within a
10 metal's crystal lattice.

In this application, the term "metal" shall be deemed to
mean and include metals and alloys that absorb hydrogen and
its isotopes. A deuteride is a compound with deuterium and
a tritide is a compound with tritium. The term "elevated
15 temperatures" shall mean above ambient temperatures, say 20
degrees Celsius.

Metals usually form crystal lattices in which the nuclei
of the metals are packed closely together. The crystal
lattice of a metal also can have two or more phases,
20 depending on such factors as temperature, pressure and
impurities. Hydrogen, including its heavy isotopes
deuterium and tritium, can diffuse into the interstices of
the crystal lattice. Further, if a suitable potential is
applied to the crystal lattice, the diffusion of deuterium
25 can be enhanced so that extremely high effective pressures
or activities of deuterium can be obtained in the crystal
lattice. The relationship between the applied voltage and
the effective pressure or activity of the deuterium within
the crystal lattice can be calculated using the Nernst
30 equation. If the effective pressure or activity of the
deuterium is sufficiently great, the deuterium nuclei may
undergo fusion or some other nuclear process and produce
excess heat.

Pons and Fleischmann claim to have achieved
35 electrochemical-fusion by immersing a palladium electrode in
heavy water with a supporting electrolyte, lithium
deuterioxide (LiOD), and then using electrolysis to
dissociate the heavy water. See "Electrochemically Induced

1 Nuclear Fusion of Deuterium," J. Electroanal. Chem. 261
(1989) 301-308, and more recently, in the same journal 287
(1990) 293-348. However, the Pons and Fleischmann method of
electrochemical fusion has several disadvantages.

5 First, Pons and Fleischmann employed an aqueous
solution, which limits the usefulness of their invention to
a temperature range below the boiling point of water
(approximately 100 degrees Celsius at 1 atmosphere
pressure). This low-temperature operation leads to low
10 efficiency in commercial applications.

Second, the Pons and Fleischmann invention requires the
use of expensive materials such as Pd and its alloys because
the aqueous solution will result in an oxide film on almost
all other host metals. This oxide film will normally impede
15 diffusion of the deuterium into the metal. Accordingly, the
host metal must be a noble metal that will not form
diffusion-impeding oxide films in the presence of water or
oxygen.

Third, Pons and Fleischmann used a negative Pd electrode
20 which will cause positive deuterium ions and positive alkali
ions to migrate to the negative Pd electrode to form alloys
with Pd and impede diffusion of the deuterium into the
metal.

Fourth, the Pons and Fleischmann invention dissociates
25 its solvent, heavy water, and therefore requires substantial
amounts of solvent in order to function, unless recombined.

Fifth, the Pons and Fleischmann invention creates
substantial amounts of deuterium and oxygen gas, thereby
creating a danger of a chemical explosion.

30 Sixth, the Pons and Fleischmann invention might not work
efficiently with metals including palladium. At the
temperatures employed by Pons and Fleischmann, palladium has
two single crystalline phases. However, at elevated
temperatures, Pd as well as many other metals have only one
35 crystalline phase. Each crystalline phase has a different
packing density and atomic arrangement and it is therefore
unlikely that fusion or other possible nuclear processes
will take place under the same conditions for the different

1 crystalline phases. Thus, having multiple crystalline
phases might reduce the efficiency of any nuclear reaction
that was induced.

Attempts to achieve electrochemical fusion, as claimed
5 by Pons and Fleischmann, have reportedly been unable to
detect fusion by-products consistently. The present
inventors are unable to determine whether their invention
employs fusion or some other reaction or principle.
Accordingly, the present inventors describe their invention
10 only as relating to a "nuclear process"; the determination
of the theory of the reaction taking place is left to
others.

It is therefore an object of this invention to provide
an electrochemical method of inducing a nuclear reaction at
15 a temperature that will be commercially useful for power
generation.

It is a further object of this invention to provide such
a method that will avoid the formation of diffusion-impeding
oxide films on the host metal.

20 It is a further object of this invention to provide such
a method that will enable operation at a temperature
sufficiently high that the host metal is in a single phase.

It is a still further object of this invention to
provide such a method that will use negatively charged
25 deuterium ions.

It is a still further object of this invention to
provide such a method that will not dissociate the solvent
of the electrolyte.

It is a still further object of this invention to
30 provide such a method that will employ inexpensive
materials.

It is a still further object of this invention to
provide such a method that will not generate oxygen so that
the risk of a chemical explosion may be avoided.

35 It is a still further object of this invention to
provide a recycling system for deuterium and lithium.

Disclosure of Invention

These and other objects are achieved by dissolving a

1 hydrogen isotope-containing component capable of providing a
source of a hydrogen isotope (preferably an alkali
deuteride) into a substantially non-aqueous molten salt to
form an electrolytic solution, immersing a metal into the
5 electrolytic solution and then applying a sufficiently high
electrical potential and current density to the metal and
the electrolytic solution to dissociate the alkali deuteride
and to force sufficient amounts of deuterium into the metal
at sufficient pressures to increase the activity of the
10 deuterium and to initiate the nuclear reaction.

Using a liquid salt avoids oxidation of the host metal
because of the lack of oxygen and also provides an extremely
reducing environment that eliminates any oxides that may
form on the metal's surface. Use of a liquid salt also
15 permits a wide range of working temperatures, depending on
the particular salt selected. For example, a salt could be
selected that was solid at room temperature, but would melt
at operating temperatures.

The avoidance and elimination of oxidation allows the
20 use of many different metals because no oxide film will
impede diffusion of the deuterium into the metal. Thus,
less expensive metals can be used. The lack of oxygen also
avoids the possibility of a chemical explosion from
accumulated oxygen with hydrogen and its isotopes.

25 The ability to use a higher temperature allows the
generation of heat at commercially valuable temperatures and
also enhances deuterium diffusion into the metal. It also
allows operation at a temperature in which the host metal is
in a single phase.

30 Because the source for deuterium is the alkali deuteride
dissolved in the liquid salt, the salt can be selected so
that dissociation of the alkali deuteride will not
dissociate the salt. Further, the dissociation potential of
the alkali deuteride (preferably lithium deuteride) is
35 lower than the dissociation potential of heavy water.
Therefore, the power required for the electrolysis is
reduced substantially.

Brief Description of the Drawings

1 Figure 1 is a schematic view of an apparatus according to this invention.

 Figure 2 is a cross sectional view of the apparatus in Figure 1 through the line 2-2.

5 Figure 3 is a schematic view of an improved mass and energy flow arrangement according to this invention incorporating a lithium deuteride recycling system.

 Figure 4 is a schematic diagram of the lithium deuteride recycling system incorporated into the electrolysis cell.

10 Best Mode for Carrying Out the Invention

 Referring to Figure 1, a crucible 10 (preferably aluminum) is filled with a eutectic lithium chloride-potassium chloride (LiCl-KCl) salt and heated above 350 degrees Celsius (and preferably between 370 and 400 degree Celsius) in an inert gas environment (preferably argon or helium) at atmospheric pressure or greater to form a molten salt solution. Alternatively, the salt could be heated in an evacuated environment or in a deuterium environment. Sufficient alkali deuteride (preferably lithium deuteride (LiD)) is then dissolved into the molten salt to form a saturated electrolytic solution 12. However, the solution is not required to be saturated and is expected to be unsaturated under operating conditions. A positive electrode 14 made of a transition metal, preferably palladium, which has been thermally annealed (preferably torched and remelted), is immersed in the electrolytic solution 12, as is a negative electrode 16, preferably made of aluminum. At the preferred temperature, the palladium positive electrode 14 will be in a single phase during reaction.

30 A constant current density (preferably 200 milliamperes/cm² or higher) is passed at a sufficiently high rate between the electrodes 14 and 16 to dissociate the lithium deuteride and to increase the activity of the deuterium in the positive electrode 14 so that a nuclear reaction takes place. Experimental results indicate that reaction takes place at 1.8 volts or higher. The experiments have been reproduced, but not consistently. The preferred salt for the practice

1 of this invention is a lithium chloride-potassium chloride
eutectic molten salt, the preferred electrolyte is lithium
deuteride and the preferred host metal is palladium, as
indicated above. However, other salts and other alkali
5 deuterides may be employed in the practice of this
invention, as may other metals. For example, the molten
salt could be an organometallic salt, an alkali halide, or
an alkali hydroxide, and their mixtures. The alkali
deuteride could be lithium deuteride, sodium deuteride or
10 potassium deuteride. Alternatively, alkaline earth metal
(Group IIA) deuterides (such as magnesium deuteride, calcium
deuteride, or strontium deuteride) or Group IIIA metal
deuterides (such as aluminum deuteride) could be employed.
The metal also could be a transition metal, such as
15 titanium, palladium, vanadium, tantalum, niobium, zirconium,
hafnium, nickel, iron, or cobalt, and their alloys, and
intermetallics based on the lanthanum and actinium series.

Many of the advantages of using a molten salt solution
in forcing hydrogen into a metal lattice are described and
20 discussed in the article entitled "Controlled Electrolyte
Environments and Their Use For Studying and Modifying
Materials Properties: Potentials for Employment in Practical
Devices," Solid State Ionics 28-30 (1988) 1078-1083.

RECYCLING SYSTEM

25 A problem that arises with use of the cell structure
depicted in Fig. 1 is that deuterium gas evolved from the
palladium anode escapes. Further, lithium is depleted from
the system and combines with the aluminum cathode to form
 Li_xAl_y (nominally "LiAl"), which is a by-product of no
30 further use in this application. These reactions make the
system discontinuous because it runs down relatively
quickly; it is anticipated that the system would run down in
a matter of hours or days instead of months or years. This
also results in a low efficiency in the use of LiD
35 electrolyte and adds to the cost of the system.
Accordingly, it would be desirable to provide some type of
recycling system for the deuterium gas and lithium.

Figure 3 shows a schematic diagram of a recycling system for the deuterium gas and lithium.

1 for a lithium and deuterium recycling system. This
recycling is preferably achieved by using tungsten,
molybdenum, nickel or iron for the cathode, preferably
molybdenum. These metals do not form compounds with lithium
5 and also have very limited solubilities for lithium, so that
the lithium will plate on the surface. As indicated above,
the excess heat from the fusion cell is used to generate
useful electricity. Some of this electricity is used by the
cell for electrolysis of the lithium deuteride solution.
10 Unused deuterium gas evolves from the palladium electrode
and, because the cell's temperature is higher than the
melting point of lithium, liquid lithium plates on the
cathode. The deuterium gas and liquid lithium are
recombined to form lithium deuteride. This recombination
15 should release additional heat due to the negative enthalpy
of formation and could be used for additional power
generation. The lithium deuteride then is recycled through
the fusion cell.

A separate deuterium gas supply is preferred in order to
20 insure proper formation of lithium deuteride because
deuterium will be consumed in the reaction creating excess
heat.

Figure 4 shows a cell similar to the cell shown in
Figure 1, with a lithium and deuterium recycling system. As
25 is the case in Figure 1, a crucible 20 (preferably of the
same material as the cathode, namely molybdenum) is filled
with a lithium chloride-potassium chloride (LiCl-KCl)
eutectic salt and initially heated by a heating element 24
above 350 degrees Celsius (and preferably between 370 and
30 400 degrees Celsius) in an inert gas environment (preferably
argon or helium) at atmospheric pressure or greater to form
a molten salt solution. A similar system using pure
deuterium gas or an evacuated environment can also be
employed. Sufficient lithium deuteride (LiD) is dissolved
35 into the molten salt to form a saturated electrolytic
solution 22. A positive electrode 26 preferably made of
torched and annealed palladium, but having a significant
horizontal extent is immersed in the electrolyte.

1 22. A negative electrode 30, comprising a metallic sponge
(to present a large reaction surface) made of a metal that
does not form alloys with lithium and has little lithium
solubility, such as tungsten, molybdenum, nickel or iron
5 (and preferably molybdenum) is also immersed in the
electrolytic solution but spaced apart from and above the
positive electrode. The negative electrode 30 is
approximately horizontally coextensive with the interior of
the crucible 20. The positive electrode 26 should be
10 electrically isolated from the rest of the cell.

In operation, excess deuterium D_2 that does not react
with the positive electrode 26 bubbles upwards into the
negative electrode 30. Simultaneously, lithium Li that has
been dissociated from the lithium deuteride plates onto the
15 negative electrode 30 and is held in its absorbent
structure. The electrochemically-generated deuterium D_2 gas
that is not incorporated into the host lattice then reacts
with the lithium Li to form lithium deuteride LiD, which
redissolves into the electrolytic solution 22. Preferably,
20 a source of additional deuterium S is provided below the
negative electrode 30 to react with the lithium Li in the
negative electrode 30. Any lithium Li that does not react
with deuterium D_2 gas in the negative electrode 30 will
float to the surface as a liquid because the electrolytic
25 solution 22 is heated above lithium's melting point. Excess
deuterium or deuterium from the source S then can react with
the lithium Li floating on the surface of the electrolytic
solution 22.

It is anticipated that this recycling system would
30 increase the lifetime of a system by at least one, and
perhaps more, orders of magnitude.

TORCHED PALLADIUM

It is preferable that the palladium used in the cell be
torched palladium which has a very porous structure. It
35 appears to be much more effective than other forms of
palladium. Any other means to prepare such a porous
structure may be obvious in this application and may be
usable as well.

1 Industrial Applicability

5 The apparatus and process of this invention have a wide range of applications. In the utility industry, these applications include electric power generation, dwelling heating, and self-sustaining power generation for remote areas. In the manufacturing and processing industries, the applications could include chemical production and materials production. In transportation, the applications could include vehicles, such as cars, trains, buses, trucks, 10 ships, and aircraft. Other applications are limited only by the imagination.

It will be apparent to those skilled in the art that many modifications may be made without departing from the scope and spirit of this invention. The term "transition 15 metals" shall include transition metals and their alloys and also shall include elements in the lanthanum and actinium series and intermetallics based thereon. The term "molten salt" shall mean and include mixtures of salts. The invention has been described only with respect to single 20 preferred embodiment and no limitation is to be implied or inferred except as may be set forth in the appended claims.

CLAIMS

What is claimed is:

1. A process for inducing nuclear reactions at temperatures above ambient temperature, comprising:

applying an electrical potential and current density to an electrolytic solution having a hydrogen isotope-containing component capable of providing a source of a hydrogen isotope and a metal, by applying an electrical potential and current density to said metal and solution to diffuse the hydrogen isotope into the metal to initiate the nuclear reaction; and

enhancing the rate of diffusion and activity of said hydrogen isotope by minimizing oxide formation on the metal.

2. A process for effecting enhanced diffusion and

dissolution of deuterium into a metal using electrochemically assisted means, comprising:

dissolving an alkali deuteride into a substantially non-aqueous molten salt to form an electrolytic solution;

immersing a metal in said electrolytic solution; and

applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution to enhance the diffusion and dissolution of deuterium into said metal and activity of said deuterium in said metal.

3. A process as in claim 2 wherein the metal is selected from the group consisting of transition metals and their alloys.

4. A process as in claim 3, wherein said transition metal is torched palladium having a porous structure.

5. A process as in claim 2, wherein said alkali deuteride is lithium deuteride.

6. An electrolytic cell comprising:

a substantially non-aqueous molten salt;

an alkali deuteride dissolved in said salt to form an electrolytic solution;

a metal immersed in said electrolytic solution; and
means for applying an electrical potential and current density to said metal and said electrolytic solution.

1 the group consisting of transition metals and their alloys.

8. A process for electrochemically-assisted nuclear reaction, comprising:

5 dissolving an alkali deuteride into a substantially non-aqueous liquid salt to form an electrolytic solution;

immersing a metal in said electrolytic solution; and

applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution to diffuse sufficient amounts of deuterium into said metal at sufficient activity to initiate the nuclear reaction.

10 9. A process for electrochemically-assisted nuclear reaction, comprising:

dissolving an alkali earth metal deuteride into a substantially non-aqueous liquid salt to form an electrolytic solution;

15 immersing a metal in said electrolytic solution; and
applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution to diffuse sufficient amounts of deuterium into said metal at sufficient activity to initiate the nuclear reaction.

20 10. A process for electrochemically-assisted nuclear reaction, comprising:

dissolving a Group IIIA metal deuteride into a substantially non-aqueous liquid salt to form an electrolytic solution;

25 immersing a metal in said electrolytic solution; and
applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution to diffuse sufficient amounts of deuterium into said metal at sufficient activity to initiate the nuclear reaction.

30 11. A process for electrochemically-assisted nuclear reaction, comprising:

dissolving an alkali tritide into a substantially non-aqueous liquid salt to form an electrolytic solution;

35 immersing a metal in said electrolytic solution; and
applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution to diffuse sufficient amounts of tritium into said metal at sufficient activity to initiate the nuclear reaction.

1 sufficient activity to initiate the nuclear reaction.

12. A process for electrochemically-assisted nuclear reaction, comprising:

5 dissolving an alkali earth metal tritide into a substantially non-aqueous liquid salt to form an electrolytic solution;

immersing a metal in said electrolytic solution; and
applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution
10 to diffuse sufficient amounts of tritium into said metal at sufficient activity to initiate the nuclear reaction.

13. A process for electrochemically-assisted nuclear reaction, comprising:

dissolving a Group IIIA metal tritide into a
15 substantially non-aqueous liquid salt to form an electrolytic solution;

immersing a metal in said electrolytic solution; and
applying a sufficiently high electrical potential and current density to said metal and said electrolytic solution
20 to diffuse sufficient amounts of tritium into said metal at sufficient activity to initiate the nuclear reaction.

14. A process as in any one of claims 8 to 13, wherein said substantially non-aqueous liquid salt comprises a molten salt.

25 15. A process as in claim 14, wherein said molten salt is selected from the group consisting of organometallic salts, alkali halides, alkali hydroxides and mixtures of them.

16. A process as in any one of claims 8 to 13 wherein said metal is selected from the group consisting of transition
30 metals and their alloys.

17. A process as in claim 16 wherein said transition metal is selected from the group consisting of titanium, palladium, vanadium, tantalum, niobium, zirconium, nickel, cobalt, iron and their alloys.

35 18. A process as in claim 8, wherein:

said applying step dissociates said alkali deuteride into an alkali and deuterium gas;

wherein only a diffused portion of said deuterium

1 initiates said nuclear reaction leaving a remaining portion
of said deuterium gas which evolves out of said solution;
and

wherein said alkali accumulates in said solution;

5 further comprising:

reacting said alkali with said remaining deuterium gas
and with additional deuterium gas to form an alkali
deuteride; and

dissolving said alkali deuteride into said electrolytic
10 solution to recycle said alkali and said deuterium.

19. A process as in claim 18, wherein said alkali is
lithium.

20. A process as in claim 19, wherein said salt is a
lithium chloride-potassium chloride eutectic salt heated
15 above 350 degrees Celsius.

21. A process as in claim 20, wherein said metal is
palladium.

22. A process as in claim 21, wherein said palladium is
torched palladium having a porous structure.

20 23. A process as in claim 22, wherein said electrical
potential is at least 1.8 volts and said current density is
at least 200 milliamps per square centimeter.

24. An electrolytic cell having a recycling system,
comprising:

25 a crucible;

an inert gas contained in said crucible providing an
inert gas atmosphere;

a substantially non-aqueous molten salt melted in said
crucible in said inert gas atmosphere;

30 an alkali deuteride dissolved in said salt to form an
electrolytic solution;

a first electrode comprising a metal selected from the
group consisting of tungsten, molybdenum, nickel, iron and
their alloys, immersed in said electrolytic solution;

35 a second electrode comprising a metal selected from the
group consisting of palladium, titanium, tantalum, vanadium,
nickel, niobium, iron, cobalt, zirconium, and their alloys,
immersed in said electrolytic solution: and

1 means for applying an electrical potential and current density to said electrodes and said electrolytic solution, whereby:

5 said alkali deuteride is electrolyzed into an alkali and deuterium, whereby:

a diffused portion of said deuterium is diffused into said second electrode to generate excess heat;

a remaining portion of said deuterium is evolved as deuterium gas; and

10 said alkali is deposited onto said first electrode; a source of additional deuterium gas;

means for combining said remaining deuterium gas and said additional deuterium gas with said alkali to form an alkali deuteride; and

15 means for dissolving said alkali deuteride into said electrolytic solution.

25. A cell as in claim 24 wherein said alkali is lithium.

26. A cell as in claim 24, wherein said first electrode comprises molybdenum.

20 27. A cell as in claim 24, wherein said second electrode comprises palladium.

28. A cell as in claim 27, wherein said palladium is torched palladium having a porous structure.

29. An electrolytic cell, comprising:

25 a molybdenum crucible;

a lithium chloride-potassium chloride eutectic salt in said crucible, wherein said salt has been heated above 350 degrees Celsius to form a molten salt;

30 sufficient amounts of lithium deuteride dissolved into said molten salt to form an electrolytic solution;

a positive electrode comprising torched and remelted palladium immersed in said electrolytic solution;

35 a negative electrode comprising molybdenum immersed in said electrolytic solution and spaced apart from said first electrode;

a source of electrical current density and voltage capable of applying a current density of at least 200 milliamps per square centimeter at a voltage of at least 1.8

- 1 volts between said first and second electrodes;
whereby said electrical current density and voltage
dissociate said lithium deuteride into lithium and
deuterium;
- 5 whereby a diffused portion of said deuterium diffuses
into said palladium in said positive electrode and a
remaining portion of said deuterium evolves as deuterium gas
at said positive electrode;
whereby said lithium is deposited as liquid lithium
10 metal at said negative electrode and floats to said surface;
means for combining said liquid lithium metal and said
remaining portion of said deuterium gas to create recycled
lithium deuteride; and
means for introducing said recycled lithium deuteride
15 into said electrolytic solution.
30. An electrolytic cell, comprising:
a crucible;
a heat source for heating said crucible;
a lithium chloride-potassium chloride eutectic salt in
20 said crucible, wherein said salt has been heated by said
heat source above 350 degrees Celsius to form a molten salt;
sufficient amounts of lithium deuteride dissolved into
said molten salt to form an electrolytic solution;
a negative electrode comprising porous molybdenum
25 immersed in said electrolytic solution;
a positive electrode comprising torched and remelted
palladium immersed in said electrolytic solution underneath
said negative electrode;
a source of electrical current density and voltage
30 capable of applying a current density of at least 200
milliamps per square centimeter at a voltage of at least 1.8
volts between said positive and negative electrodes;
whereby said electrical current density and voltage
dissociate said lithium deuteride into lithium and
35 deuterium;
whereby a diffused portion of said deuterium diffuses
into said palladium in said positive electrode and a
remaining portion of said deuterium evolves into unused

deuterium gas bubbles at said positive electrode and said unused deuterium gas bubbles float upwards into said negative electrode;

whereby said lithium is deposited as liquid lithium metal in said negative electrode;

whereby said unused deuterium gas reacts with said liquid lithium metal to form recycled lithium deuteride and whereby said recycled lithium deuteride dissolves into said electrolytic solution.

- 10 31. An electrolytic cell, according to claim 29 or 30, wherein said salt is heated in an inert gas environment.
32. An electrolytic cell, according to claim 31, wherein said environment is at least at atmospheric pressure.
33. An electrolytic cell, according to claim 31, wherein
15 said environment is below atmospheric pressure.
34. An electrolytic cell, according to claim 29 or 30, wherein said salt is heated in a deuterium environment.
35. An electrolytic cell, according to claim 34 wherein said environment is at least at atmospheric pressure.
- 20 36. An electrolytic cell, according to claim 34, wherein said environment is below atmospheric pressure.
37. An electrolytic cell, according to claim 29 or 30, wherein said salt is heated in an evacuated environment.
38. An electrolytic cell, according to claim 29 or 30,
25 further comprising:

means for introducing additional deuterium gas below the surface of said electrolytic solution whereby additional deuterium gas bubbles to the surface of said electrolytic solution.

- 30 39. An electrolytic cell, according to claim 38, wherein said solution is an unsaturated electrolytic solution.
40. An electrolytic cell, according to claim 38, wherein said solution is a saturated electrolytic solution.

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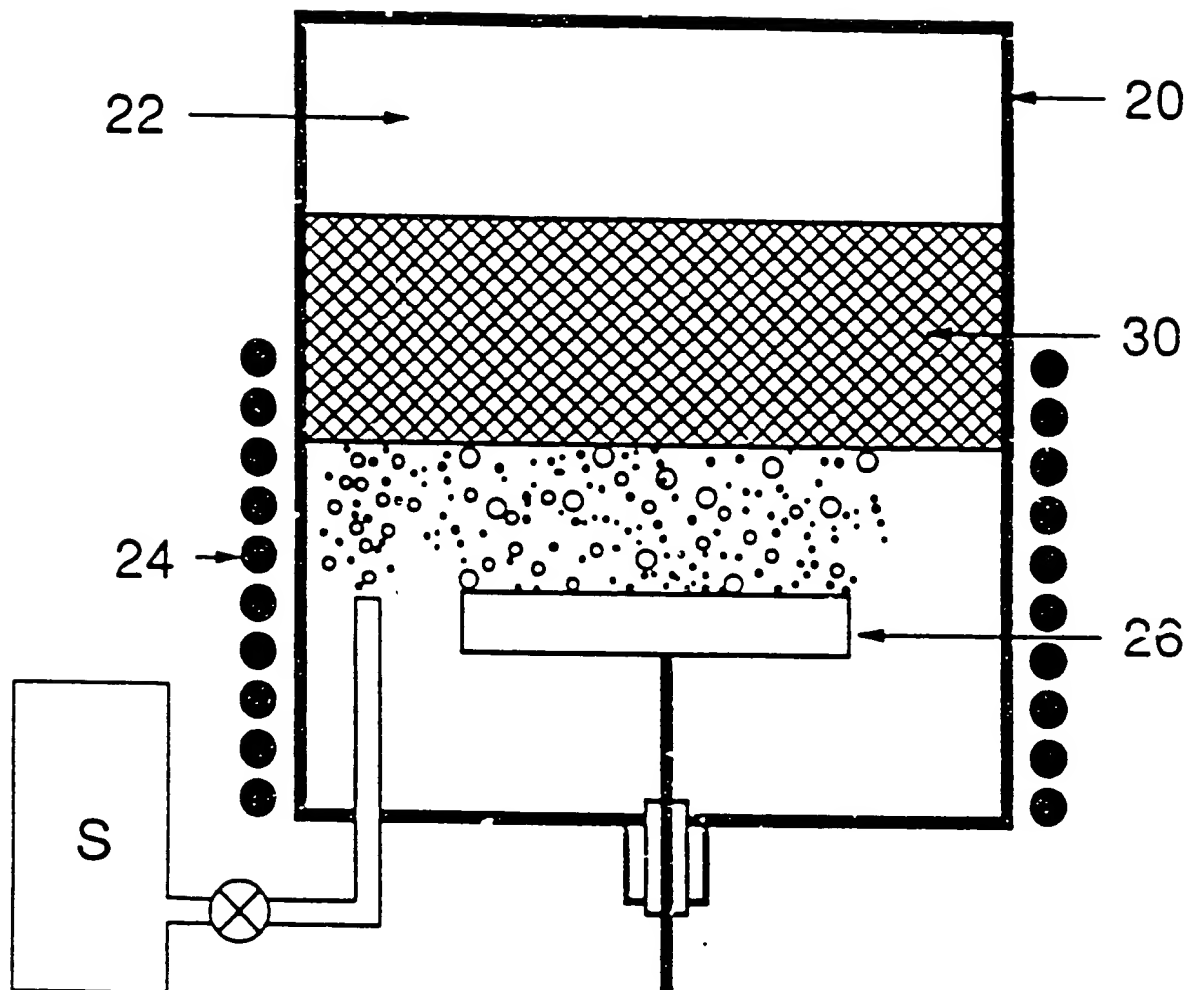


FIGURE 4

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 90/06419

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)*				
According to International Patent Classification (IPC) or to both National Classification and IPC				
Int.Cl. 5 G21B1/00				
II. FIELDS SEARCHED				
Minimum Documentation Searched ⁷				
Classification System	Classification Symbols			
Int.Cl. 5	G21B			
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁸				
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹				
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³		
P, X	WO, A, 9 013 127 (CERAMATEC) 1 November 1990 see page 3, line 35 - page 6, line 9 see page 7, line 5 - line 14 see claim 8	1-8 14-17		
A	---	9		
P, Y	WO, A, 9 013 125 (BRIGHAM YOUNG UNIVERSITY) 1 November 1990 see page 7, line 6 - page 8, line 10 see claims 1-4, 6	1		
P, Y	EP, A, 0 392 324 (SEMICONDUCTOR ENERGY LAB.) 17 October 1990 see column 1, line 39 - line 55 see column 2, line 18 - line 26 ---	1		
	--- -/--			
¹⁰ Special categories of cited documents: <table border="0"> <tr> <td> ^{"A"} document defining the general state of the art which is not considered to be of particular relevance ^{"E"} earlier document but published on or after the international filing date ^{"I"} document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) ^{"O"} document referring to an oral disclosure, use, exhibition or other means ^{"P"} document published prior to the international filing date but later than the priority date claimed </td> <td> ^{"T"} later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention ^{"X"} document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step ^{"Y"} document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. ^{"A"} document member of the same patent family </td> </tr> </table>			^{"A"} document defining the general state of the art which is not considered to be of particular relevance ^{"E"} earlier document but published on or after the international filing date ^{"I"} document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) ^{"O"} document referring to an oral disclosure, use, exhibition or other means ^{"P"} document published prior to the international filing date but later than the priority date claimed	^{"T"} later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention ^{"X"} document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step ^{"Y"} document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. ^{"A"} document member of the same patent family
^{"A"} document defining the general state of the art which is not considered to be of particular relevance ^{"E"} earlier document but published on or after the international filing date ^{"I"} document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) ^{"O"} document referring to an oral disclosure, use, exhibition or other means ^{"P"} document published prior to the international filing date but later than the priority date claimed	^{"T"} later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention ^{"X"} document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step ^{"Y"} document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. ^{"A"} document member of the same patent family			
IV. CERTIFICATION				
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report			
19 NOVEMBER 1991	25 NOV 1991			
International Searching Authority	Signature of Authorized Officer			
EUROPEAN PATENT OFFICE	CAPOSTAGNO E <i>[Signature]</i>			

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED) FROM THE SECOND SHEET

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,A	<p>FUSION TECHNOLOGY. vol. 18, no. 3, November 1990, LAGRANGE PARK, ILLINOIS US pages 505 - 511; ILIC ET AL.: 'Investigations of the deuterium-deuterium fusion reaction in cast, annealed, and cold-rolled palladium' see abstract</p> <p style="text-align: center;">---</p>	4-5

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. US 9006419
SA 51620

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 19/11/91

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9013127	01-11-90	None	
WO-A-9013125	01-11-90	None	
EP-A-0392324	17-10-90	JP-A- 2271289	06-11-90

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